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EXPERIENCE OF USING MULTILAYER VIRTUAL PARTITIONING IN LABORATORY COMPLEX CONSTRUCTION

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Abstract. Continuous development of information technology especially complicates the task of conducting practical exercises in the process of studying them. The use of typical virtual laboratory complexes brings partial solution for this problem, but completely abstracts the student. The article shows how the use of virtual and real components in a laboratory complex allows more fully use existing equipment, increase the number of students and deepen their practical skills in constructing modern data transmission systems.

Key words: *the equipment of the laboratory complex, virtualization technology, virtual separation of network infrastructure, virtual routers, virtual workstations.*

Introduction

The process of studying network technologies involve the interaction of a student with communication equipment. The formation and consolidation of student's skills in managing network devices is provided by laboratory classes. Building and maintaining laboratory facilities in educational institutions is a complex task that requires considerable resources. For example, performing one laboratory work on any of the topics in the section "Routing" requires a set of three routers for each of the lab teams that the standard group size of 15–20 students requires 15–18 such devices. In today conditions acquisition, use, supply and support of such a large number of modern telecommunication devices is impossible for most educational institution. This is the reason of rising interest to a variety of network virtualization technologies, which provide the formation and consolidation of student's skills in management of network devices increases in education [1]. In the last 5−8 years a variety of software applications is also actively developing- platform network emulations, which allow you to create a fairly complex networking topology using the models of telecommunication devices (routers, switches, firewalls, etc.) and simulate their operation in real time [2]. Additional attractiveness of such emulation platforms like Cisco Packet Tracer [3], Graphical Network Simulator (GNS3) [4], UNetLab/EVE-NGB [5] consists that the simulated network devices are controlled by the same command-line interface (Command Line Interface − CLI) as their real counterparts. In GNS3 and EVE-NGB systems such ability is provided by applying additional layers of virtualization with the use of auxiliary emulation subsystems, such as Dynamips [6] or QEMU [7]. In this case, the emulation subsystem performs the functions of a software hypervisor, designed to accommodate virtual network components, such as routers or switches from Cisco Systems, and provides the ability to use customized versions of those operating systems (in this case Cisco IOS) that run on their actual prototypes. Authenticity of emulation in this case is determined by how adapted versions of operating systems is differ from real (it should be noted that the development of subsystems emulate these differences are becoming less noticeable). The obvious advantage of using this approach for of the laboratory complex completion, in comparison of using pure hardware, is the smaller number of used physical resources. However, it should be taken into account that the implementation of a pure software approach, even with the use of freely distributed software simulation of the network components (due to the use of layered emulation), significantly tightens the requirements to the characteristics and configuration of workstations of the classroom. In addition, because the operating system of modern telecommunication devices is usually protected by producers copyright, the ability to use formal training process, even customized versions of these systems, can be questioned. But the necessity and expediency of virtualization technologies that are the driving force of a new technological revolution [8] using in the process of learning modern networking technologies do not raise doubts today. The approach described further offers a balanced manner of virtual and real components using in laboratory building a that allows you to increase the efficiency of existing equipment, to intensify the learning process and at the same time, to avoid using irrelevant material components.

Virtualization of the network infrastructure

The basic principle of virtualization is the separation of the physical resource between independent virtual objects. In telecommunications systems this principle is applied in the formation of the virtual overlay networks [9] to create the virtual network slices [10] over the real (carrier) network infrastructure. According to the classification of Network Functions Virtualisation (NFV) ETSI Industry Specification Group (ISG) this approach is called Virtual Partitioning [11]. This approach can be used to upgrade the laboratory facilities of the institution by distributing the computational resources of routers and the real servers of the underlay network between the virtual routers and the virtual PC, and communication resources of the physical channels between appropriate virtual channels, as shown on fig. 1.

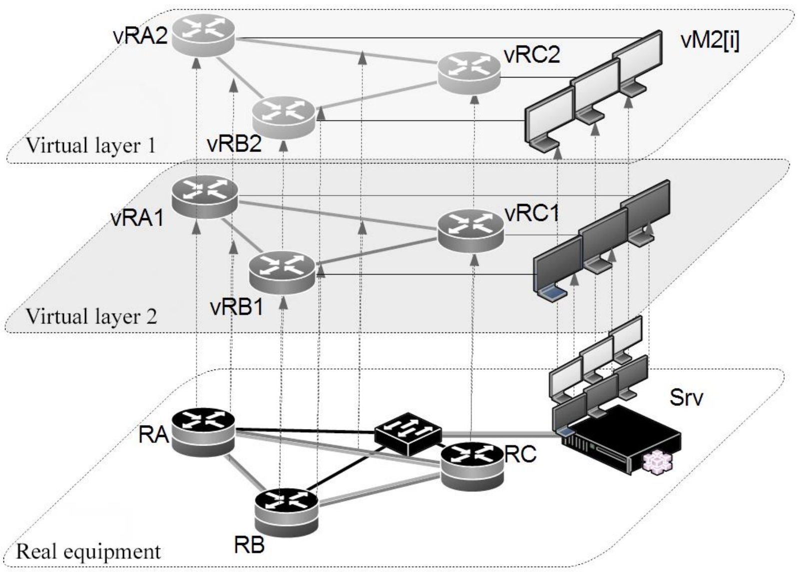

Figure 1

For successive connections between the routers fractional of the laboratory complex uses digital streams formed in the channel (interface) E1, the parameters of which are defined in recommendation ITU-T G. 704 [12]. Distributed resource in this case is the throughput (data rate) the channel resource allocation is performed according to the scheme of temporary separation (Time Division Multiplexing – TDM). This solution allows to create up to 30 virtual channels (interfaces) in one physical channel that can be used to perform laboratory works on “Routing”. Since these channels have a fixed bandwidth, they can also be used when performing work on the management and monitoring of quality of service (Service Level Agreement-SLA, Quality of Service – QoS).

For virtual IEEE 802.3 (Ethernet) compounds in the laboratory complex traditionally [1][8] uses a technology called Virtual Local Area Network (VLAN). The allocated resource is a function of switching Ethernet frames for MAC addresses, which in this case is performed by the switch only within a virtual network, and the frames that are transmitted through shared across VLAN trunks, are provided with a special label [13].

For virtual Internet Protocol (IP) compounds in the laboratory complex is expedient to apply the technology of Virtual Routing and Forwarding (VRF), which is supported by leading manufacturers of communication equipment [14; 15]. The separation in this case is performed at the network level of information interaction, and the allocated resource is a function of routing IP packets, which occurs only within the virtual VRF instance [15].

To simulate the workstations in the lab complex, it is advisable to use a standard solution desktop virtualization (Virtual Desktop Infrastructure – VDI). In this case, the resources of the systems of processing and storage of the virtualization server are separated between the virtual desktops. Modern hypervisors allow to create laboratory work a number of virtual PC even on servers with very modest performance sufficient and provides the possibility to connect them to the infrastructure of the laboratory complex through the virtual switches [16]. The use of the complex described above technologies will allow you to create multi-layered network infrastructure, virtual components, which, as will be shown, can be successfully used in the laboratory classes.

The construction and operation of the laboratory complex

To build the laboratory complex was used the routers RA, RB and RC, switch SW and the server Srv whose characteristics are summarized in table 1. At the Srv was created by virtual PC that simulated the subscriber connection, RA, RB, and RC was organized by the virtual VRF instance that mimicked the routers, the switch SW used to manage the virtual infrastructure of the complex when performing laboratory work.

Table 1

Designation	Model	Type of OS	OS version	RAM
RA	Cisco 7206VXR	C7200ADVIPSERVICESK9-M	15.1(4)M2	256MB
RB	Cisco 2811	C2800NM-ADVENTERPRISEK9-IVS-LI-M	15.1(4)M7	256MB
RC	Cisco 2801	C2801-ADVIPSERVICESK9-M	15.1(2)T2	384MB
SW	WS-C2960-24TC-L	C2960-LANBASE-MZ.122-25	12.2	32MB
Srv	HP Proliant DL160 G6	VMware ESXi 5.5.0	5.5.0	8192MB

For successive connections to the routers were installed interface modules, whose characteristics are summarized in table 2. A variety of used equipment is described by the fact that the creation of the laboratory complex was used the routers and interface modules which were available at the beginning of works on creation of the laboratory complex. Connection ITU-T G. 704 FE1 was made with UTP cat 5e. with connectors RJ-48C which have been made by the scheme cross-over E1-G. 703/G. 704 in accordance with the requirements for the establishment of connections to the interface modules routers Cisco Systems [17].

Table 2

Designation	Model	Name	Number of modules	Number of ports	The number of virtual flows
RA	Cisco 7206VXR	PA-MCX-8TE1	1	8	30
RB	Cisco 2811	NM-2CE1T1-PRI	1	2	30
RC	Cisco 2801	VWIC-2MFT-E1-DI	2	2	2

The scheme of the laboratory complex is shown on fig. 2

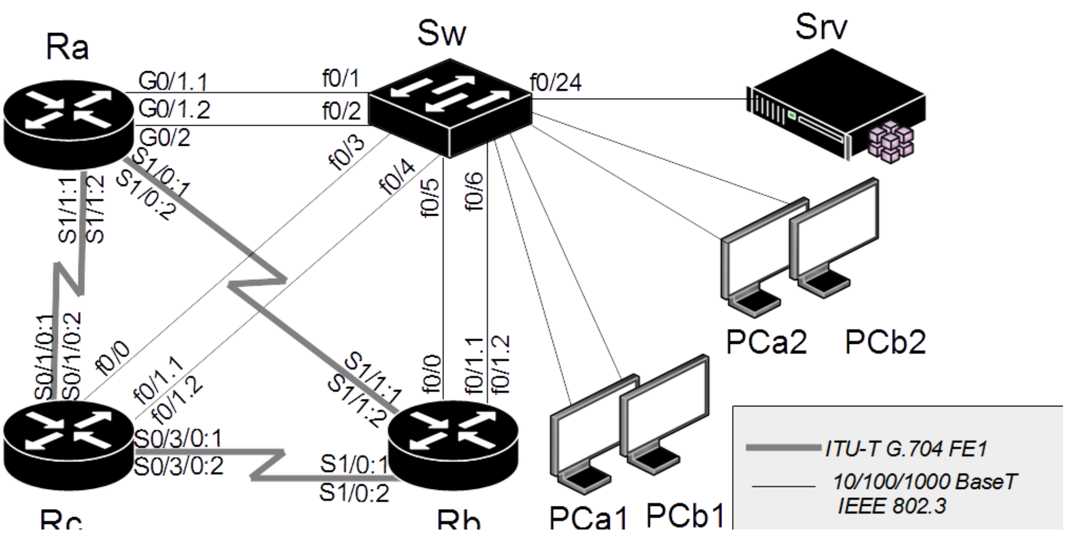

Figure 2

For the trial operation of the complex was adapted methodical instructions to performance of laboratory works №№ 6.2.2.5, 6.4.3.5, 7.1.3.6, 7.2.3.7, 8.2.4.5, 9.2.2.8, 10.1.3.5, 10.2.3.4 on "OSPF" and "EIGRP Protocol" course "CCNA Routing and Switching. Scaling Networks”. Adapted methods include additional guidance on the use of virtual routers and virtual workstations (PC). As the operating system for user virtual machines were chosen Debian v.4.9.82-1, released under the GNU GPLv3 license. When performing laboratory work each of the teams has at its disposal a virtual layer which includes two or three virtual PC and virtual routers (VRF instance), which was established on the routers RA, RB and RC. When performing laboratory work management components of the virtual layer was carried out with workstations and PCa1 PCa2 one of which is used for configuring virtual routers, one for configuring a virtual PC. In total during the trials were performed 16 laboratory works during each of which the virtual equipment of the laboratory complex he worked two teams of students at the same time, and two teams of students performed the same lab work on real equipment (one kit of three routers). Despite the complexity of the adapted techniques of laboratory work, students who worked with the virtual equipment did not experience additional difficulties and successfully coped with the tasks in the allotted time. Thus, in the process of laboratory work in addition to required for successful completion of the course “CCNA Routing and Switching. Scaling Networks” management skills communications equipment, these students receive additional skills to manage virtual routers and virtual workstations. The testing showed full functionality of the laboratory complex and confirmed the correctness of the solutions that were chosen for its construction.

Measurement characteristics of the laboratory complex

To assess the prospects for future use of the laboratory complex and determine the directions of its modernization was carried out further testings and measurements.

The first group of testings was carried out to assess the impact of throughput of the serial channels on the characteristics of communications between stations within the same virtual layer, and assess the possible mutual influence of virtual layers through a supporting infrastructure. During the testings on the first virtual layer of the information bit rate is linearly increased from 2 to 28 slots channel DS0 E1 with step 2. On the second (control) virtual layer of information, the bit rate remained unchanged. In each measurement was determined by the average value of delays for cyclic transmission of 4000 byte ICMP packets between a virtual PC for each layer. The obtained results show that with a linear increase in the number of DS0 in the flow of the first layer, the delay of packets transmitted between the virtual PC of this layer decreased exponentially (Fig. 3a – solid line), and time delays in the second (control) virtual layer remained practically unchanged (Fig. 3a – dotted line).

a)

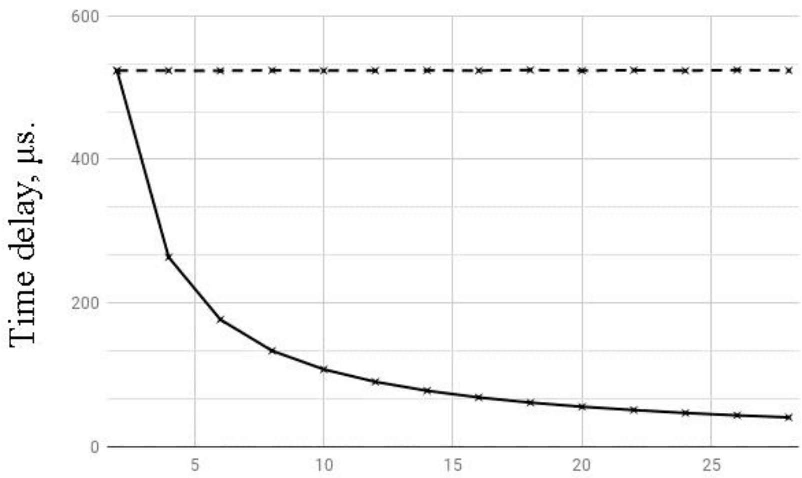

Figure 3*a*

b)

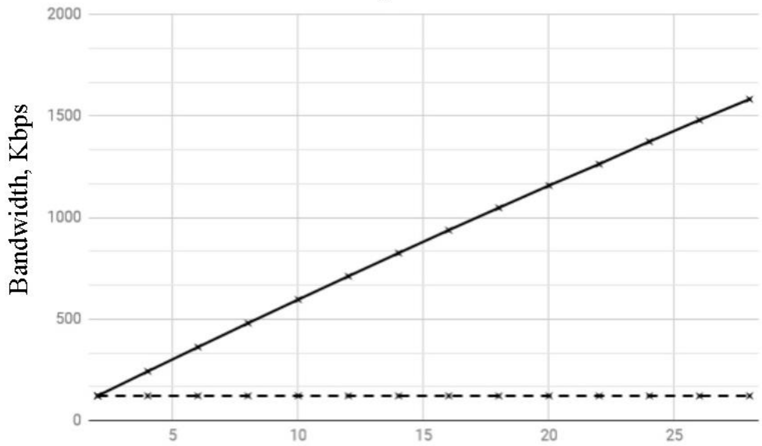

Figure 3*b*

Based on the data that were obtained during the first test group, according to the formula:

$$BW(i) = 1/k(i), \text{ where } k=64103 \text{ bps.}$$

Were calculated estimates of changes a bandwidth of virtual channels BW of the first and second virtual layers depending on the number of channel intervals DS0 in the digital stream of the first layer. The results of the assessments showed a linear increase in throughput of a virtual channel of the first layer (Fig.3b-solid line) and the constancy of the bandwidth of the virtual channel in the second layer (Fig.3b-dashed line) the linear increase of information rate of the corresponding digital stream of the first layer. Thus, when conducting measurements and the subsequent processing of the results was confirmed by the ability of proportional bandwidth control virtual channel a virtual layer and the lack of mutual influence among virtual channels, organized in a single physical interface.

The second group of testings were performed to assess the stability of functioning and "load capacity" of the entire laboratory complex as a whole. The second group of testings evaluated the performance of carrier network infrastructure laboratory complex at a linear increasing from 1 to 15 number of placed on layers of virtual infrastructure. The efficiency of the complex was determined by the ability to perform the functions and processes of routing that are required for laboratory work. During the testings on the routers and the server of the laboratory complex was determined by the percentage used of the maximum available amounts of memory (RAM).

a)

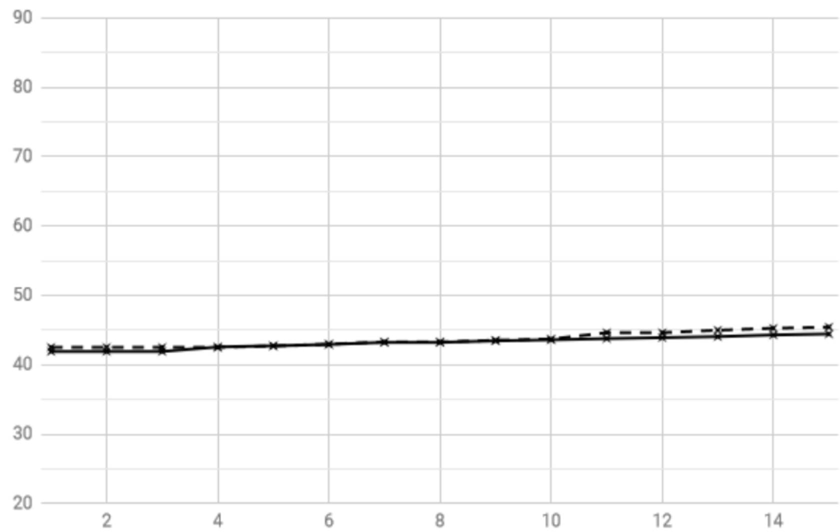

Figure 4*a*

b)

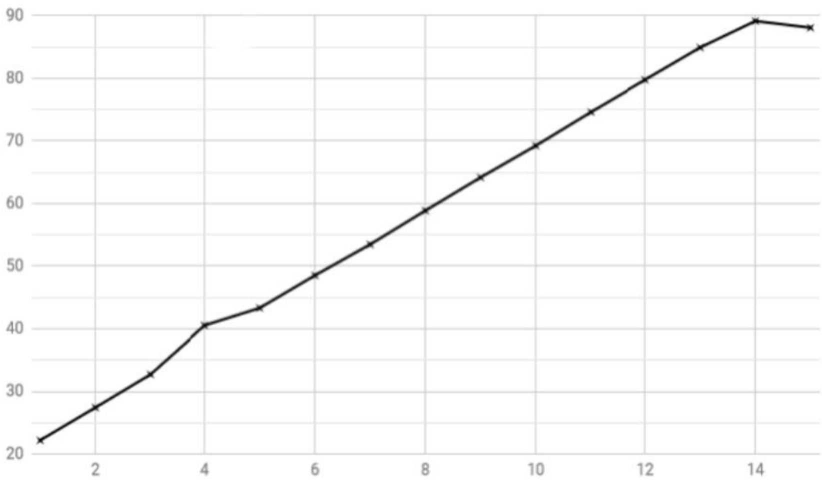

Figure 4*b*

The results show that the download RAM routers RA and RB when the number of them placed on the virtual router (VR) were increased slightly (by no more than 0.2 %) (Fig. 4a, solid and dashed lines, respectively). By increasing the number of VR from 1 to 15 RA and RB are functioning normally, the CPU usage on carrier routers does not exceed 1 %. At the same time, the tests showed that loading the RAM in the server Srv has increased on average by 2.5 % when enabled, each new virtual machine (VM), which gave an increase in load by 5 % when enabled, each new virtual layer which was used by two VMS (Fig. 4b). Therefore, the organization of more than 14 virtual layers (28 active VM), the server Srv, because of 90 % loading of the RAM, starts to operate unstable. Crashes of server operation manifested in the form of temporary loss of control of the active VM, which indicates the need to replace this component in case of a possible modernization of this laboratory complex.

The conclusion

The using of described in this paper technologies of virtualization and Virtual Partitioning provide the ability to build a full-scale multi-layered network infrastructure of virtual components for communications equipment manufacturers such as Cisco Systems, Juniper, and Huawei. The paper shows how use of these technologies in the laboratory complex construction lead to discover additional capabilities of existing equipment and enhance the efficiency of its use. Conducted laboratory studies showed the operability of designed complex and confirmed the correctness of technical solutions chosen for its construction. Additional verification testings have helped to clarify the operational characteristics of the system and to define possible directions of its further use and modernization.

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